(12) UK Patent Application (19) GB (11) 2 303 439 (13) A

(43) Date of A Publication 19.02.1997

(21) Application No 9515020.7

(22) Date of Filing 21.07.1995

(71) Applicant(s)
Rolls-Royce plc

(Incorporated in the United Kingdom)

65 Buckingham Gate, LONDON, SW1E 6AT, United Kingdom

(72) Inventor(s)
Jeffrey Douglas Willis
Douglas Mathieson
Ian James Toon
Jane Emily Bickerton

(74) Agent and/or Address for Service
M A Gunn
Rolls-Royce plc, Patents Department, PO Box 31, Moor Lane, DERBY, DE24 8BJ, United Kingdom

(51) INT CL[6]
F23R 3/40

(52) UK CL (Edition O)
F4T TAR3 T101 T1107 T1110 T1118 T1120
U1S S1987

(56) Documents Cited
US 5355668 A US 4081958 A

(58) Field of Search
UK CL (Edition N) F4T TAR3
INT CL[6] F23R 3/00 3/16 3/26 3/40

(54) **A gas turbine engine combustion chamber**

(57) A gas turbine engine combustion chamber (28) comprises a primary combustion zone (36), a secondary combustion zone (40) and a tertiary combustion zone (44). A pair of radial flow swirlers (60,62) and associated fuel injectors (64,66) supply a fuel and air mixture into the primary combustion zone (36). An axially upstream extending lip (74) between the two radial flow swirlers (60,62) is provided with a coating of a catalyst material (126)(Fig 3) on both its surfaces. The catalyst material (126) provides stable location of the flamefront in the primary combustion zone (36) even though there may be pressure fluctuations in the air flow into the primary combustion zone (36). This reduces undesirable amplification of pressure fluctuations in the air flow which may induce resonance and hence damage some of the components of the gas turbine engine (10). Additionally the inner surfaces of the wall (30,32) defining one or more of the three combustion zones (36,40,44) are provided with a coating of a catalyst material (126). The catalyst material may be palladium oxide, rhodium, platinum, or tin for example.

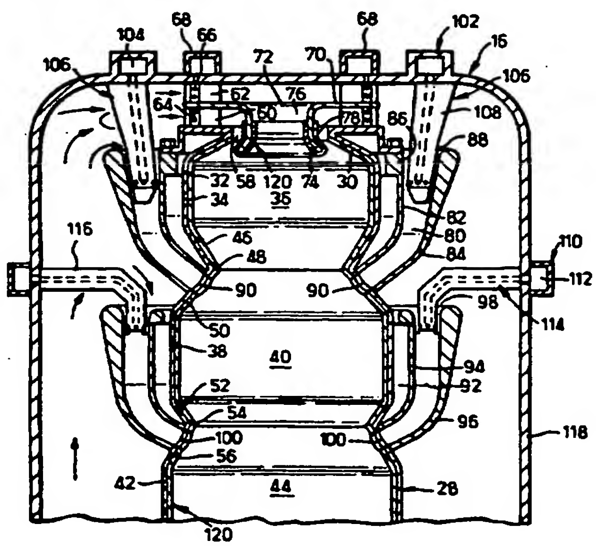

Fig.2.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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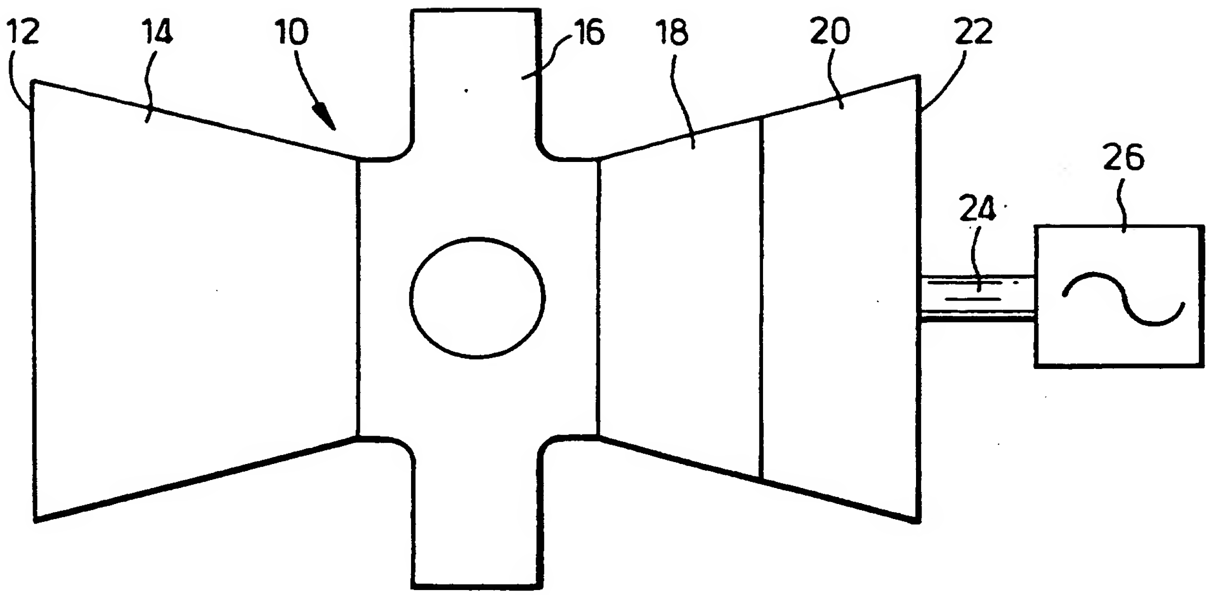

Fig.1.

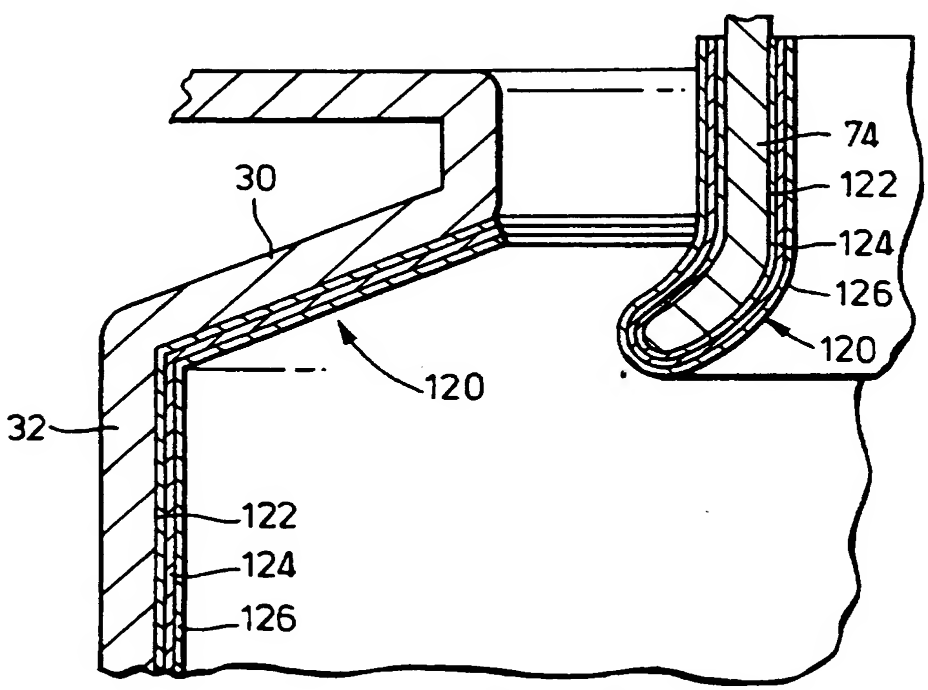

Fig.3.

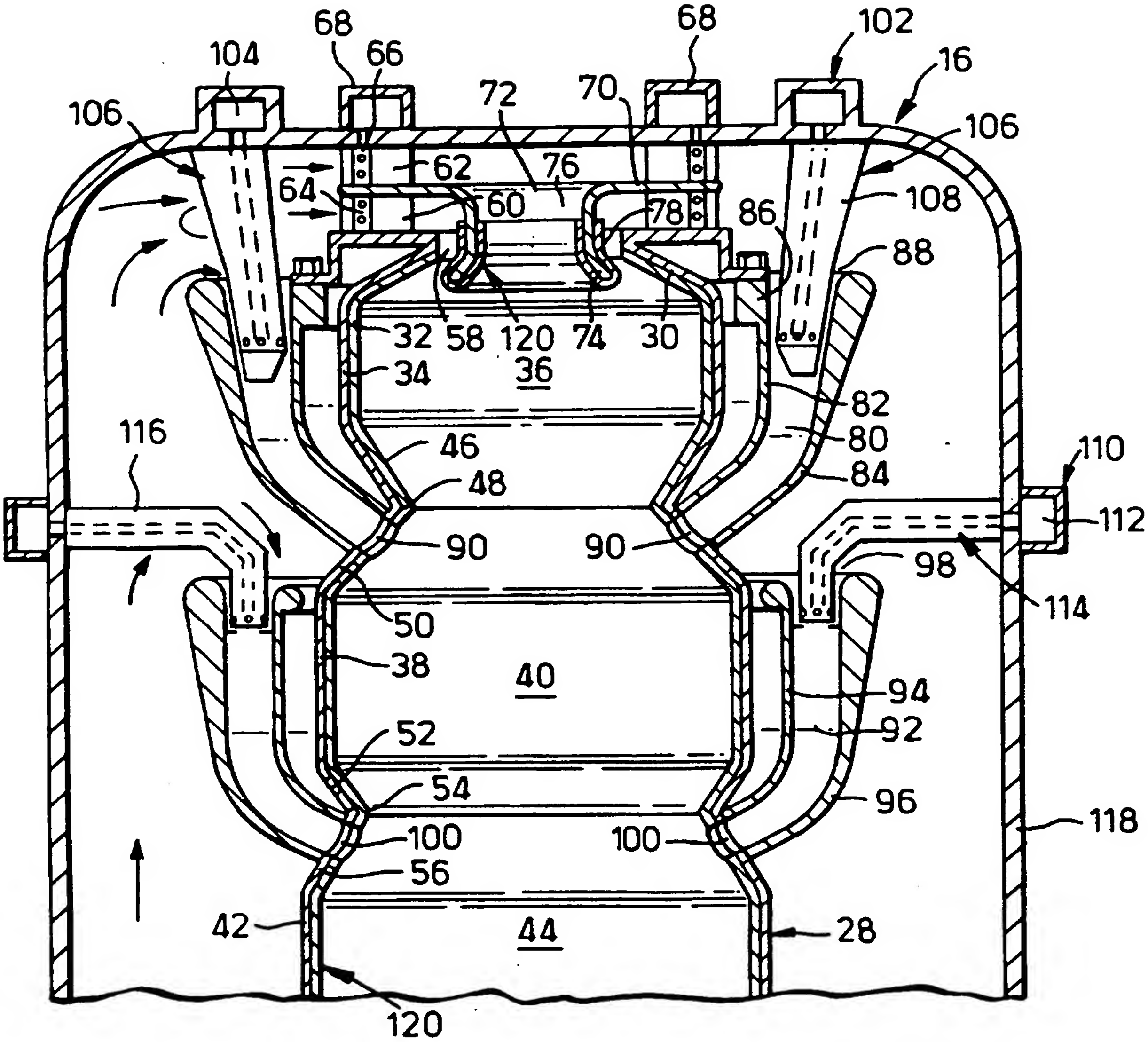
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Fig.2.

A GAS TURBINE ENGINE COMBUSTION CHAMBER

The present invention relates to a gas turbine engine combustion chamber.

In order to meet the emission level requirements, for industrial low emission gas turbine engines, staged combustion is required in order to minimise the quantity of the oxide of nitrogen (NOx) produced. Currently the emission level requirement is for less than 25 volumetric parts per million of NOx for an industrial gas turbine exhaust. The fundamental way to reduce emissions of nitrogen oxides is to reduce the combustion reaction temperature, and this requires premixing of the fuel and all the combustion air before combustion occurs. The oxides of nitrogen (NOx) are commonly reduced by a method which uses two stages of fuel injection. Our UK patent no. 1489339 discloses two stages of fuel injection to reduce NOx. Our International patent application no. WO92/07221 discloses two and three stages of fuel injection. In staged combustion, all the stages of combustion seek to provide lean combustion and hence the low combustion temperatures required to minimise NOx. The term lean combustion means combustion of fuel in air where the fuel to air ratio is low i.e. less than the stoichiometric ratio. In order to achieve the required low emissions of NOx and CO it is essential to mix the fuel and air uniformly.

The industrial gas turbine engine disclosed in our International patent application no. WO92/07221 uses a plurality of tubular combustion chambers, whose longitudinal axes are arranged in generally radial directions. The inlets of the tubular combustion chambers are at their radially outer ends, and transition ducts connect the outlets of the tubular combustion chambers with a row of nozzle guide vanes to discharge the hot exhaust gases axially into the turbine sections of the gas turbine engine. Each of the tubular

combustion chambers has two coaxial radial flow swirlers which supply a mixture of fuel and air into a primary combustion zone. An annular secondary fuel and air mixing duct surrounds the primary combustion zone and supplies a mixture of fuel and air into a secondary combustion zone.

One problem associated with gas turbine engines is caused by pressure fluctuations in the air, or gas, flow through the gas turbine engine. Pressure fluctuations in the air, or gas, flow through the gas turbine engine may lead to severe damage, or failure, of components if the frequency of the pressure fluctuations coincides with the natural frequency of a vibration mode of one or more of the components. Also the pressure fluctuations may be generated within the combustion chamber. If as the pressure fluctuations pass through the combustion chamber the pressure fluctuations cause the combustion energy release process to become unstable, then amplification of the pressure fluctuations results, and the amplification may be up to 20 times. These amplified pressure fluctuations obviously cause more severe damage than the unamplified pressure fluctuations. The pressure fluctuations in the air, or gas, flow through the gas turbine engine is difficult to eliminate.

Combustion processes are prevented if the resultant flame temperature is below a critical level, typically 1550^{O}K for hydrocarbon fuels. These conditions exist at the walls of combustion chambers where the metal temperatures are typically less than 1100^{O}K. If the fuel to air ratio is varying prior to combustion due to pressure fluctuations in the airflow to the combustion chamber, then the resultant flame temperature at the walls of the combustion chamber will also fluctuate. The heat removed from the flame by the walls of the combustion chamber and by wall cooling air can result in the resultant flame temperature being too low to sustain combustion and hence extinction of the flame occurs in

the vicinity of the walls of the combustion chamber. If the conditions exist such that the pressure fluctuations in the airflow result in fluctuating flame temperatures at the walls of the combustion chamber above and below the flame extinction temperature then intermittent combustion occurs. This intermittent combustion results in intermittent amplification of the pressure fluctuations. The intermittent combustion may occur in the primary, the secondary and the tertiary combustion zones.

If a flamefront exists at regions within the combustion chamber where an unstable flow exists, even with steady gas flows, then unsteady heat energy release occurs, resulting in fluctuations in pressure. If the flow of air, or gas, into these regions also has pressure fluctuations then the degree of unsteady heat energy release is increased, especially if the unsteady air flow results in a fluctuating fuel to air mixture ratio. If the fuel to air ratio at these regions becomes too low then combustion cannot exist because the resultant flame temperature is too low. Thus pressure fluctuations in the air flow will result in intermittent combustion in regions of unstable flow, which will create large pressure fluctuations. These regions exist at the downstream ends of the ducts leading from the two radial flow swirlers to the primary combustion zone.

One solution for reducing or eliminating the amplification of the pressure fluctuations in the combustion chamber is to increase the mean combustion temperature. However, in the case of a staged combustion chamber with lean burn as discussed above, an increase in the mean combustion temperature from 1800^{O}K to 1900^{O}K to reduce combustion chamber amplification of pressure fluctuations, has the undesirable side effect of increasing NOx.

Another solution for reducing or eliminating the amplification of the pressure fluctuations in the

combustion chamber is to provide noise attenuators, to reduce, or eliminate, the pressure fluctuations, in the air flow upstream of the combustion chambers. Thus for the same amount of amplification by the combustion chambers, smaller initial pressure fluctuations result in smaller resultant amplified pressure fluctuations, which may be acceptable. Alternatively the pressure fluctuations may be reduced to a small enough level such that the flame temperature at the walls of the combustion chamber does not vary sufficiently to cause alternate extinguishing and relighting of the flame, and hence no amplification. However, this has been tried and has been found not to work.

The present invention seeks to provide a novel gas turbine engine combustion chamber which overcomes the above mentioned problem.

Accordingly the present invention provides a gas turbine engine combustion chamber comprising at least one combustion zone defined by at least one peripheral wall, at least one fuel and air mixing duct to supply air and fuel respectively into the combustion zone, the fuel and air mixing duct is defined by at least one wall, the at least one wall defining the fuel and air mixing duct has a coating of catalyst material on at least a downstream portion of the at least one wall to control the position of the flamefront immediately downstream of the fuel and air mixing duct in the at least one combustion zone to reduce amplification of pressure fluctuations in the combustion chamber.

Preferably the at least one peripheral wall has a coating of catalyst material on substantially all of its inner surface to control the position of the flamefront adjacent to the at least one peripheral wall in the at least one combustion zone to reduce amplification of pressure fluctuations in the combustion chamber.

The combustion chamber may comprise a primary combustion zone and a secondary combustion zone

downstream of the primary combustion zone, the at least one fuel and air mixing duct supplies air and fuel into the primary combustion chamber.

Preferably the combustion chamber comprises a primary combustion zone, a secondary combustion zone downstream of the primary combustion zone and a tertiary combustion zone downstream of the secondary combustion zone, the at least one fuel and air mixing duct supplies air and fuel into the primary combustion chamber.

Preferably the peripheral wall is annular.

Preferably the at least one fuel and air mixing duct comprises a first radial flow swirler and fuel injection means arranged to supply fuel and air into a first passage, and a second radial flow swirler and fuel injection means arranged to supply fuel and air into a second passage, the first and second radial flow swirlers are arranged coaxially.

Preferably the first and second radial flow swirlers comprise a plurality of circumferentially spaced vanes, the fuel injection means are arranged to inject fuel between the vanes of the first radial flow swirler and the fuel injection means are arranged to inject fuel between the vanes of the second radial flow swirler.

The at least one fuel and air mixing duct may comprise at least one primary fuel and air mixing duct arranged to supply fuel and air into the primary combustion zone and at least one secondary fuel and air mixing duct arranged to supply fuel and air into the secondary combustion zone.

Preferably the at least one fuel and air mixing duct comprises at least one primary fuel and air mixing duct arranged to supply fuel and air into the primary combustion zone, at least one secondary fuel and air mixing duct arranged to supply fuel and air into the secondary combustion zone and at least one tertiary fuel and air mixing duct arranged to supply fuel and air into the tertiary combustion zone.

The at least one peripheral wall may have a coating of catalyst material on its inner surface to control the position of the flamefront adjacent to the at least one peripheral wall in the primary combustion zone to reduce amplification of pressure fluctuations in the combustion chamber and the at least one peripheral wall has a coating of catalyst material on its inner surface to control the position of the flamefront adjacent to the at least one peripheral wall in the secondary combustion zone to reduce amplification of pressure fluctuations in the combustion chamber.

Preferably the at least one peripheral wall has a coating of catalyst material on its inner surface to control the position of the flamefront adjacent to the at least one peripheral wall in the primary combustion zone to reduce amplification of pressure fluctuations in the combustion chamber, the at least one peripheral wall has a coating of catalyst material on its inner surface to control the position of the flamefront adjacent to the at least one peripheral wall in the secondary combustion zone to reduce amplification of pressure fluctuations in the combustion chamber, and the at least one peripheral wall has a coating of catalyst material on its inner surface to control the position of the flamefront adjacent to the at least one peripheral wall in the tertiary combustion zone to reduce amplification of pressure fluctuations in the combustion chamber.

Preferably the catalyst material comprises any catalytically active material including palladium oxide, platinum, rhodium or tin.

Preferably the at least one wall defining the fuel and air mixing duct has a thermal barrier coating, the coating of catalyst material is arranged on the thermal barrier coating.

Preferably the at least one peripheral wall has a thermal barrier coating, the coating of catalyst material is arranged on the thermal barrier coating.

Preferably the thermal barrier coating comprises a metallic bond coating and a ceramic coating.

Preferably the metallic bond coating comprises a MCrAlY.

Preferably the ceramic coating comprises yttria stabilised zirconia or alumina.

The present invention also provides a gas turbine engine combustion chamber comprising a primary combustion zone and a secondary combustion zone downstream of the primary combustion zone, the primary and secondary combustion zones are defined in part by at least one peripheral wall, primary fuel and air mixing duct means to supply air and fuel into the primary combustion zone, secondary fuel and air mixing duct means to supply air and fuel into the secondary combustion zone, the at least one peripheral wall has a coating of catalyst material on substantially all of its inner surface defining the primary combustion zone or has a coating of catalyst material on substantially all of its inner surface defining the secondary combustion zone to control the position of the flamefront adjacent to the at least one peripheral wall in the primary combustion zone or the secondary combustion zone respectively to reduce amplification of pressure fluctuations in the combustion chamber.

The at least one peripheral wall may have a coating of catalyst material on substantially all of its inner surface defining the primary combustion zone and has a coating of catalyst material on substantially all of its inner surface defining the secondary combustion zone.

The present invention also provides a gas turbine engine combustion chamber comprising a primary combustion zone, a secondary combustion zone downstream of the primary combustion zone and a tertiary combustion zone downstream of the secondary combustion zone, the primary, secondary and tertiary combustion zones are defined in part by at least one peripheral wall, primary fuel and

air mixing duct means to supply air and fuel into the primary combustion zone, secondary fuel and air mixing duct means to supply air and fuel into the secondary combustion zone, tertiary fuel and air mixing duct means to supply air and fuel into the tertiary combustion zone, the at least one peripheral wall has a coating of catalyst material on substantially all of its inner surface defining the primary combustion zone, has a coating of catalyst material on substantially all of its inner surface defining the secondary combustion zone or has a coating of catalyst material on substantially all of its inner surface defining the tertiary combustion zone to control the position of the flamefront adjacent to the at least one peripheral wall in the primary combustion zone, the secondary combustion zone or the tertiary combustion respectively to reduce amplification of pressure fluctuations in the combustion chamber.

The at least one peripheral wall may have a coating of catalyst material on substantially all of its inner surface defining the primary combustion zone and has a coating of catalyst material on substantially all of its inner surface defining the secondary combustion zone.

The at least one peripheral wall may have a coating of catalyst material on substantially all of its inner surface defining the tertiary combustion zone.

The present invention will be more fully described by way of example with reference to the accompanying drawings, in which:-

Figure 1 is a view of a gas turbine engine having a combustion chamber according to the present invention.

Figure 2 is an enlarged longitudinal cross-sectional view through the combustion chamber shown in figure 1.

Figure 3 is a further enlarged longitudinal cross-sectional view through the upstream end of the combustion chamber shown in figure 2.

An industrial gas turbine engine 10, shown in figure 1, comprises in axial flow series an inlet 12, a

compressor section 14, a combustion chamber assembly 16, a turbine section 18, a power turbine section 20 and an exhaust 22. The turbine section 18 is arranged to drive the compressor section 14 via one or more shafts (not shown). The power turbine section 20 is arranged to drive an electrical generator 26 via a shaft 24. However the power turbine section 20 may be arranged to provide drive for other purposes. The operation of the gas turbine engine 10 is quite conventional, and will not be discussed further.

The combustion chamber assembly 16 is shown more clearly in figures 2 and 3. The combustion chamber assembly 16 comprises a plurality of, for example nine, equally circumferentially spaced tubular combustion chambers 28. The axes of the tubular combustion chambers 28 are arranged to extend in generally radial directions. The inlets of the tubular combustion chambers 28 are at their radially outermost ends and their outlets are at their radially innermost ends.

Each of the tubular combustion chambers 28 comprises an upstream wall 30 secured to the upstream end of an annular wall 32. A first, upstream, portion 34 of the annular wall 32 defines a primary combustion zone 36, a second, intermediate, portion 38 of the annular wall 32 defines a secondary combustion zone 40 and a third, downstream, portion 42 of the annular wall 32 defines a tertiary combustion zone 44. The second portion 38 of the annular wall 32 has a greater diameter than the first portion 34 of the annular wall 32, and similarly the third portion 42 of the annular wall 32 has a greater diameter than the second portion 38 of the annular wall 32. The downstream end of the first portion 34 has a first frustoconical portion 46 which reduces in diameter to a throat 48. A second frustoconical portion 50 interconnects the throat 48 and the upstream end of the second portion 38. The downstream end of the second portion 38 has a third frustoconical portion 52 which

reduces in diameter to a throat 54. A fourth frustoconical portion 56 interconnects the throat 54 and the upstream end of the third portion 42.

A plurality of equally circumferentially spaced transition ducts are provided, and each of the transition ducts has a circular cross-section at its upstream end. The upstream end of each of the transition ducts is located coaxially with the downstream end of a corresponding one of the tubular combustion chambers 28, and each of the transition ducts connects and seals with an angular section of the nozzle guide vanes.

The upstream wall 30 of each of the tubular combustion chambers 28 has an aperture 58 to allow the supply of air and fuel into the primary combustion zone 36. A first radial flow swirler 60 is arranged coaxially with the aperture 58 in the upstream wall 30 and a second radial flow swirler 62 is arranged coaxially with the aperture 58 in the upstream wall 30. The first radial flow swirler 60 is positioned axially downstream, with respect to the axis of the tubular combustion chamber 28, of the second radial flow swirler 62. The first radial flow swirler 60 has a plurality of fuel injectors 64, each of which is positioned in a passage formed between two vanes of the swirler. The second radial flow swirler 62 has a plurality of fuel injectors 66, each of which is positioned in a passage formed between two vanes of the swirler. The first and second radial flow swirlers 60 and 62 are arranged such that they swirl the air in opposite directions. The first and second radial flow swirlers 60 and 62 share a common side plate 70, the side plate 70 has a central aperture 72 arranged coaxially with the aperture 58 in the upstream wall 30. The side plate 70 has a shaped annular lip 74 which extends in a downstream direction into the aperture 58. The lip 74 defines an inner primary fuel and air mixing duct 76 for the flow of the fuel and air mixture from the first radial flow swirler 60 into the primary combustion zone

36 and an outer annular primary fuel and air mixing duct 78 for the flow of the fuel and air mixture from the second radial flow swirler 62 into the primary combustion zone 36. The lip 74 turns the fuel and air mixture flowing from the first and second radial flow swirlers 60 and 62 respectively from a radial direction to an axial direction. For a more detailed description of the use of the two radial flow air swirlers and the fuel injectors positioned in the passages formed between the swirl vanes see our International patent application no. WO92/07221. The primary fuel and air is mixed together in the passages between the vanes of the first and second radial flow swirlers 60 and 62 and in the primary fuel and air mixing ducts 76 and 78. The fuel injectors 64 and 66 are supplied with fuel from primary fuel manifold 68.

An annular secondary fuel and air mixing duct 80 is provided for each of the tubular combustion chambers 28. Each secondary fuel and air mixing duct 80 is arranged circumferentially around the primary combustion zone 36 of the corresponding tubular combustion chamber 28. Each of the secondary fuel and air mixing ducts 80 is defined between a second annular wall 82 and a third annular wall 84. The second annular wall 82 defines the radially inner extremity of the secondary fuel and air mixing duct 80 and the third annular wall 84 defines the radially outer extremity of the secondary fuel and air mixing duct 80. The axially upstream end of 86 of the second annular wall 82 is secured to a side plate of the first radial flow swirler 60. The axially upstream ends of the second and third annular walls 82 and 84 are substantially in the same plane perpendicular to the axis of the tubular combustion chamber 28. The secondary fuel and air mixing duct 80 has a secondary air intake 88 defined radially between the upstream end of the second annular wall 82 and the upstream end of the third annular wall 84.

At the downstream end of the secondary fuel and air mixing duct 80, the second and third annular walls 82 and

84 respectively are secured to the second frustoconical portion 50 and the second frustoconical portion 50 is provided with a plurality of equi-circumferentially spaced apertures 90. The apertures 90 are arranged to direct the fuel and air mixture into the secondary combustion zone 40 in a downstream direction towards the axis of the tubular combustion chamber 28. The apertures 90 may be circular or slots and are of equal flow area.

The secondary fuel and air mixing duct 80 reduces gradually in cross-sectional area from the intake 88 at its upstream end to the apertures 90 at its downstream end. The shape of the secondary fuel and air mixing duct 80 produces an accelerating flow through the duct 80 without any regions where recirculating flows may occur.

An annular tertiary fuel and air mixing duct 92 is provided for each of the tubular combustion chambers 28. Each tertiary fuel and air mixing ducts 92 is arranged coaxially around the secondary combustion zone 40. Each of the tertiary fuel and air mixing ducts 92 is defined between a fourth annular wall 94 and a fifth annular wall 96. The fourth annular wall 94 defines the radially inner extremity of the tertiary fuel and air mixing duct 92 and the fifth annular wall 96 defines the radially outer extremity of the tertiary fuel and air mixing duct 92. The axially upstream ends of the fourth and fifth annular walls 94 and 96 are substantially in the same plane perpendicular to the axis of the tubular combustion chamber 28. The tertiary fuel and air mixing duct 92 has a tertiary air intake 98 radially between the upstream end of the fourth annular wall 94 and the upstream end of the fifth annular wall 96.

At the downstream end of the tertiary fuel and air mixing duct 92, the fourth and fifth annular walls 94 and 96 respectively are secured to the fourth frustoconical portion 56, and the third frustoconical portion 56 is provided with a plurality of equi-circumferentially spaced apertures 100. The apertures 100 are arranged to

direct the fuel and air mixture into the tertiary combustion zone 44, in a downstream direction towards the axis of the tubular combustion chamber 28. The apertures 100 may be circular or slots and are of equal flow area.

The tertiary fuel and air mixing duct 92 reduces gradually in cross-sectional area from the intake 98 at its upstream end to the apertures 100 at its downstream end. The shape of the tertiary fuel and air mixing duct 92 produces an accelerating flow through the duct 92 without any regions where recirculating flows may occur.

A plurality of secondary fuel systems 102 are provided, to supply fuel to the secondary fuel and air mixing ducts 80 of each of the tubular combustion chambers 28. The secondary fuel system 102 for each tubular combustion chamber 28 comprises an annular secondary fuel manifold 104 arranged coaxially with the tubular combustion chamber 28 at the upstream end of the tubular combustion chamber 28. Each secondary fuel manifold 104 has a plurality, for example thirty two, of equi-circumferentially spaced secondary fuel injectors 106. Each of the secondary fuel injectors 106 comprises a hollow member 108 which extends axially with respect to the tubular combustion chamber 28, from the secondary fuel manifold 104 in a downstream direction through the intake of the secondary fuel and air mixing duct 80 and into the secondary fuel and air mixing duct 80. Each hollow member 108 extends in a downstream direction along the secondary fuel and air mixing duct 80 to a position, sufficiently far from the intake 88, where there are no recirculating flows in the secondary fuel and air mixing duct 80 due to the flow of air into the duct 80. The secondary fuel and air mixing duct 80 and secondary fuel injectors 106 are discussed more fully in our copending UK patent application no. 9410233.2 filed 21 May 1994.

A plurality of tertiary fuel systems 110 are provided, to supply fuel to the tertiary fuel and air mixing ducts 92 of each of the tubular combustion

chambers 28. The tertiary fuel system 110 for each tubular combustion chamber 28 comprises an annular tertiary fuel manifold 112 arranged coaxially with the tubular combustion chamber 28. The tertiary fuel manifold 112 is positioned outside a casing 118, but may be positioned in the casing. Each tertiary fuel manifold 112 has a plurality, for example thirty two, of equi-circumferentially spaced tertiary fuel injectors 114. Each of the tertiary fuel injectors 114 comprises a hollow member 116 which extends initially radially inwardly and then axially with respect to the tubular combustion chamber 28 from the tertiary fuel manifold 112 in a downstream direction through the intake 98 of the tertiary fuel and air mixing duct 92 and into the tertiary fuel and air mixing duct 92. Each hollow member 116 extends in a downstream direction along the tertiary fuel and air mixing duct 92 to a position, sufficiently far from the intake 98, where there are no recirculating flows in the tertiary fuel and air mixing duct 92 due to the flow of air into the duct 92. The tertiary fuel and air mixing duct 92 and tertiary fuel injectors 114 are discussed more fully in our copending UK patent application no. 9410233.2 filed 21 May 1994.

As discussed previously the fuel and air supplied to the combustion zones is premixed and each of the combustion zones is arranged to provide lean combustion to minimise NOx. Due to pressure fluctuations in the air flow into the tubular combustion chambers 28, the combustion process amplifies the pressure fluctuations for the reasons discussed previously and may cause components of the gas turbine engine to become damaged if they have a natural frequency of a vibration mode coinciding with the frequency of the pressure fluctuations.

Each of the tubular combustion chambers 28 is provided with a coating 120 shown more clearly in figure 3. The coating 120 comprises a thermal barrier coating

124 on the inner surface of the upstream wall 30 and the annular wall 32 which define the primary combustion zone 36, the secondary combustion zone 40 and the tertiary combustion zone 44. The thermal barrier coating 124 is also provided on the frustoconical portions 46, 50, 52 and 56. The thermal barrier coating 124 is also applied to both surfaces of the annular lip 74. The thermal barrier coating 124 generally comprises a ceramic material, for example yttria stabilised zirconia or alumina, and the thermal barrier coating 124 is bonded to the annular wall 32 by a suitable bond coat 122, for example a MCrAlY bond coat, which may be a NiCrAlY, a CoCrAlY, a NiCoCrAlY or a FeCrAlY all of which are well known to those skilled in the art, or a nickel aluminide bond coat.

Each of the tubular combustion chambers 28 is also provided with a catalyst coating 126 on the inner surface of the upstream wall 30 and the annular wall 32 which define the primary combustion zone 36, the secondary combustion zone 40 and the tertiary combustion zone 44. The catalyst coating 126 is also provided on the frustoconical portions 46, 50, 52 and 56. The catalyst coating 126 is also applied to both surfaces of the annular lip 74. The catalyst coating 126 is deposited onto the thermal barrier coating 124. The catalyst coating 126 comprises any suitable catalyst that can initiate oxidation reactions between fuel and air, for example palladium oxide, rhodium, platinum, tin etc.

The provision of the catalyst coating 126 on the inner surface of the upstream wall 30 and the annular wall 32 ensures that any fuel in the tubular combustion chamber 28 which is in a region adjacent to the upstream wall 30 and the annular wall 32 is oxidised, irrespective of whether the fuel to air ratio changes due to pressure changes in the air supplied to the tubular combustion chambers 28, provided that the temperature of the upstream wall 30 and the annular wall 32 remains at or

above a temperature of about 450°C. The catalyst coating 126 therefore prevents intermittent combustion of the fuel in regions adjacent the upstream wall 30 and the annular wall 32 of the tubular combustion chamber 28. Thus it can be seen that by maintaining continuous oxidation of any fuel in the tubular combustion chamber 28 in a region adjacent to the upstream wall 30 and the annular wall 32 that the amplification of any pressure fluctuations in the air supplied is reduced or eliminated.

Similarly the provision of the catalyst coating 126 on both surfaces of the annular lip 74 ensures that the flamefront in the primary combustion zone 36 downstream of the annular lip 74 remains substantially at a fixed location, irrespective of any instability in the flow separation from the annular lip 74 or fuel to air ratio changes due to pressure changes in the air supplied to the tubular combustion chambers 28, provided that the temperature of the annular lip 74 remains at or above a temperature of about 450°C. The catalyst coating 126 therefore prevents instability in the location of the flamefront in the primary combustion zone 36 of the tubular combustion chamber 28. Thus it can be seen that by maintaining the the flamefront at a fixed location in the primary combustion zone 36 of the tubular combustion chamber 28 that the amplification of any pressure fluctuations in the air supplied is reduced or eliminated.

The catalyst coating 126 may also be applied to the inner surfaces of the members defining the passages from the first and second radial flow swirlers 60 and 62 respectively to the primary combustion zone 36.

Although the invention is described with reference to the use of two coaxial radial flow swirlers and primary fuel injectors to provide primary fuel and air mixing ducts, the catalyst coating may also be applied to the inner surfaces of the walls of other types of primary

fuel and air mixing ducts. The invention is also applicable to staged combustion using only two stages of combustion, and is also applicable to staged combustion chambers using four or more stages of combustion and is applicable to annular combustion chambers or other shapes of combustion chamber. The invention is particularly of interest for staged combustion chambers using lean combustion.

The catalyst coating may be applied to those parts of the wall of the combustion chamber defining any one of the combustion zones, or to all combustion zones, in order to reduce amplification of the pressure fluctuations, for example only the portion of the wall of the combustion chamber defining the primary combustion zone may be coated and the portion of the wall defining the secondary and tertiary combustion zones need not have a catalyst coating if intermittent extinction and relighting does not occur in these combustion zones because of higher wall temperatures in these zones.

Claims:-

1. A gas turbine engine combustion chamber comprising at least one combustion zone defined by at least one peripheral wall, at least one fuel and air mixing duct to supply air and fuel respectively into the combustion zone, the fuel and air mixing duct is defined by at least one wall, the at least one wall defining the fuel and air mixing duct has a coating of catalyst material on at least a downstream portion of the at least one wall to control the position of the flamefront immediately downstream of the fuel and air mixing duct in the at least one combustion zone to reduce amplification of pressure fluctuations in the combustion chamber.

2. A combustion chamber as claimed in claim 1 wherein the at least one peripheral wall has a coating of catalyst material on substantially all of its inner surface to control the position of the flamefront adjacent to the at least one peripheral wall in the at least one combustion zone to reduce amplification of pressure fluctuations in the combustion chamber.

3. A combustion chamber as claimed in claim 1 or claim 2 wherein the combustion chamber comprises a primary combustion zone and a secondary combustion zone downstream of the primary combustion zone, the at least one fuel and air mixing duct supplies air and fuel into the primary combustion chamber.

4. A combustion chamber as claimed in claim 1 or claim 2 wherein the combustion chamber comprises a primary combustion zone, a secondary combustion zone downstream of the primary combustion zone and a tertiary combustion zone downstream of the secondary combustion zone, the at least one fuel and air mixing duct supplies air and fuel into the primary combustion chamber.

5. A combustion chamber as claimed in any of claims 1 to 4 wherein the peripheral wall is annular.

6. A combustion chamber as claimed in any of claims 1 to 5 wherein the at least one fuel and air mixing duct

comprises a first radial flow swirler and fuel injection means arranged to supply fuel and air into a first passage, and a second radial flow swirler and fuel injection means arranged to supply fuel and air into a second passage, the first and second radial flow swirlers are arranged coaxially.

7. A combustion chamber as claimed in claim 6 wherein the first and second radial flow swirlers comprise a plurality of circumferentially spaced vanes, the fuel injection means are arranged to inject fuel between the vanes of the first radial flow swirler and the fuel injection means are arranged to inject fuel between the vanes of the second radial flow swirler.

8. A combustion chamber as claimed in claim 3 wherein the at least one fuel and air mixing duct comprises at least one primary fuel and air mixing duct arranged to supply fuel and air into the primary combustion zone and at least one secondary fuel and air mixing duct arranged to supply fuel and air into the secondary combustion zone.

9. A combustion chamber as claimed in claim 4 wherein the at least one fuel and air mixing duct comprises at least one primary fuel and air mixing duct arranged to supply fuel and air into the primary combustion zone, at least one secondary fuel and air mixing duct arranged to supply fuel and air into the secondary combustion zone and at least one tertiary fuel and air mixing duct arranged to supply fuel and air into the tertiary combustion zone.

10. A combustion chamber as claimed in claim 3 wherein the at least one peripheral wall has a coating of catalyst material on its inner surface to control the position of the flamefront adjacent to the at least one peripheral wall in the primary combustion zone to reduce amplification of pressure fluctuations in the combustion chamber and the at least one peripheral wall has a coating of catalyst material on its inner surface to

control the position of the flamefront adjacent to the at least one peripheral wall in the secondary combustion zone to reduce amplification of pressure fluctuations in the combustion chamber.

11. A combustion chamber as claimed in claim 4 wherein the at least one peripheral wall has a coating of catalyst material on its inner surface to control the position of the flamefront adjacent to the at least one peripheral wall in the primary combustion zone to reduce amplification of pressure fluctuations in the combustion chamber, the at least one peripheral wall has a coating of catalyst material on its inner surface to control the position of the flamefront adjacent to the at least one peripheral wall in the secondary combustion zone to reduce amplification of pressure fluctuations in the combustion chamber, and the at least one peripheral wall has a coating of catalyst material on its inner surface to control the position of the flamefront adjacent to the at least one peripheral wall in the tertiary combustion zone to reduce amplification of pressure fluctuations in the combustion chamber.

12. A combustion chamber as claimed in any of claims 1 to 11 wherein the catalyst material comprises palladium oxide, platinum, rhodium or tin.

13. A combustion chamber as claimed in any of claims 1 to 12 wherein the at least one wall defining the fuel and air mixing duct has a thermal barrier coating, the coating of catalyst material is arranged on the thermal barrier coating.

14. A combustion chamber as claimed in claim 2 wherein the at least one peripheral wall has a thermal barrier coating, the coating of catalyst material is arranged on the thermal barrier coating.

15. A combustion chamber as claimed in claim 13 or claim 14 wherein the thermal barrier coating comprises a metallic bond coating and a ceramic coating.

16. A combustion chamber as claimed in claim 14 wherein the metallic bond coating comprises a MCrAlY.

17. A combustion chamber as claimed in claim 15 or claim 16 wherein the ceramic coating comprises yttria stabilised zirconia or alumina.

18. A combustion chamber for a gas turbine engine substantially as hereinbefore described with reference to and as shown in figure 2 and 3 of the accompanying drawings.

19. A gas turbine engine combustion chamber comprising a primary combustion zone and a secondary combustion zone downstream of the primary combustion zone, the primary and secondary combustion zones are defined in part by at least one peripheral wall, primary fuel and air mixing duct means to supply air and fuel into the primary combustion zone, secondary fuel and air mixing duct means to supply air and fuel into the secondary combustion zone, the at least one peripheral wall has a coating of catalyst material on substantially all of its inner surface defining the primary combustion zone or has a coating of catalyst material on substantially all of its inner surface defining the secondary combustion zone to control the position of the flamefront adjacent to the at least one peripheral wall in the primary combustion zone or the secondary combustion zone respectively to reduce amplification of pressure fluctuations in the combustion chamber.

20. A combustion chamber as claimed in claim 20 wherein the at least one peripheral wall has a coating of catalyst material on substantially all of its inner surface defining the primary combustion zone and has a coating of catalyst material on substantially all of its inner surface defining the secondary combustion zone.

21. A gas turbine engine combustion chamber comprising a primary combustion zone, a secondary combustion zone downstream of the primary combustion zone and a tertiary combustion zone downstream of the secondary combustion

zone, the primary, secondary and tertiary combustion zones are defined in part by at least one peripheral wall, primary fuel and air mixing duct means to supply air and fuel into the primary combustion zone, secondary fuel and air mixing duct means to supply air and fuel into the secondary combustion zone, tertiary fuel and air mixing duct means to supply air and fuel into the tertiary combustion zone, the at least one peripheral wall has a coating of catalyst material on substantially all of its inner surface defining the primary combustion zone, has a coating of catalyst material on substantially all of its inner surface defining the secondary combustion zone or has a coating of catalyst material on substantially all of its inner surface defining the tertiary combustion zone to control the position of the flamefront adjacent to the at least one peripheral wall in the primary combustion zone, the secondary combustion zone or the tertiary combustion respectively to reduce amplification of pressure fluctuations in the combustion chamber.

22. A combustion chamber as claimed in claim 21 wherein the at least one peripheral wall has a coating of catalyst material on substantially all of its inner surface defining the primary combustion zone and has a coating of catalyst material on substantially all of its inner surface defining the secondary combustion zone.

23. A combustion chamber as claimed in claim 22 wherein the at least one peripheral wall has a coating of catalyst material on substantially all of its inner surface defining the tertiary combustion zone.

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Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number GB 9515020.7	

Relevant Technical Fields

(i) UK Cl (Ed.N) F4T (TARS)

(ii) Int Cl (Ed.6) F23R 3/00, 3/16, 3/26, 3/40

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Search Examiner
R F PHAROAH

Date of completion of Search
5 OCTOBER 1995

Documents considered relevant following a search in respect of Claims :-
1-18

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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Category	Identity of document and relevant passages		Relevant to claim(s)
X	US 5355668 A	(WEIL) see column 6, lines 50-66 column 7, lines 17-34 column 7, lines 1-3	1, 2, 5, 12, 13, 14
X	US 4081958 A	(SCHELP) see column 2, lines 53-62	1

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